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Low frequency amplifier and oscillator using simulated inductor

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Abstract

The low frequency tuned amplifiers as well as oscillators are very difficult to design because the size of inductor becomes very large. It is impossible to realize such a large value of inductor practically. This paper presents an alternate method of using simulated inductor instead of passive component L at low frequencies. The design of simulated inductor for low frequency amplifiers and oscillators are presented. The simulation is done using the analog simulation software PSPICE and the results are shown graphically using MATLAB

Keywords: *Tuned amplifier; Hartley oscillator; Colpitts oscillato;, Simulated Inductor; Generalized Impedance Converter; Tank circuit.*

1. Introduction

The tuned amplifiers are of great use when compared with other amplifiers. The reasons are (i) the tuned amplifier consists of a tank circuit comprising an inductor and a capacitor which can be tuned to the resonant frequency. It offers low or almost zero impedance to that resonant frequency and provides amplification. At the same time, it offers high impedance to other frequencies and amplify signals of other frequencies to a little extent (ii) The value of the resistance in the tuned circuit is very less which results in low voltage drop and hence low collector power supply is needed (iii) Since the tuned circuit offers very low resistance and employs only reactive components, the power loss is minimum .Hence these amplifiers are more efficient than other amplifiers.

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But the use of tuned circuit has certain disadvantages at low frequencies. They are (i) the tuned circuit is highly selective that it cannot be used to amplify signals of low frequency because single low frequency is seldom used. (ii) Tuned amplifiers cannot be used at low frequencies because of the requirement of very large value of L in the tuned circuit [1]. This requirement of high value of L at low frequency is impossible because the size and weight of inductors become exceedingly large and Q becomes very low. Also the passive inductor requires considerable silicon area on IC chip [2]. Hence, inductors are seldom used at such low frequencies. Their characteristics are quite non-ideal. Such inductors are impossible to fabricate in monolithic form and it is incompatible with any of the modern techniques for assembling electronic systems [1]. So, it is necessary to replace such a high value of inductor by another one whose behaviour is same as that of the basic inductor.

2. Simulated inductor using active component

One method of realizing the high value of the inductor is the use of Generalized Impedance Converter (GIC) [3]. Now a days such simulated inductor is used in the design of analog filters [4]. It is also used in the design of low pass filter using FDNR (Frequency Dependant Negative Resistance) which uses transformation in the simulated inductor [5]. One more such application is, the use of simulated inductor in the generation of spectral purity sine wave with reduced harmonics [6]. This GIC consists of the active component namely the operational amplifier, resistances and capacitances as shown in Fig.1.

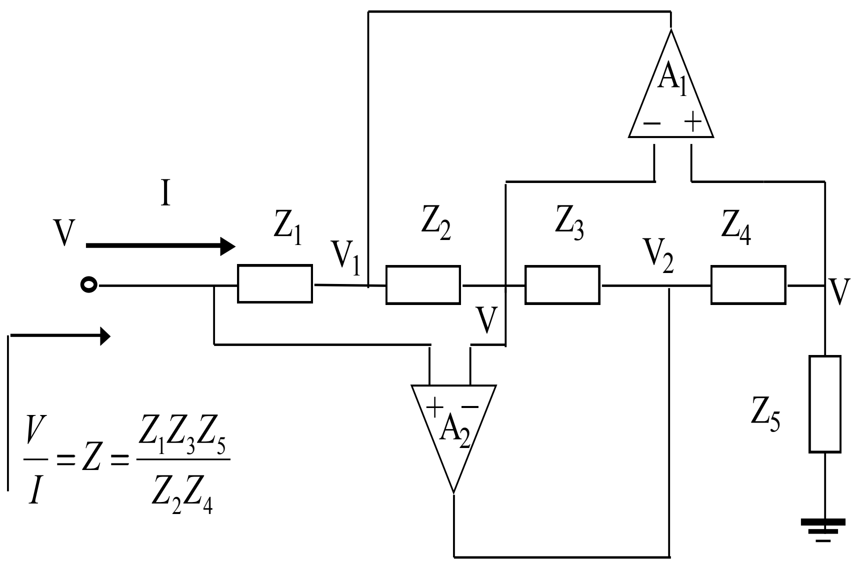

Fig.1. Antoniou Inductor simulation circuit

The impedance of the GIC circuit is obtained by writing the nodal voltages at the nodes V_1 and V_2 as shown below. The op-amp is assumed to be an ideal one with the basic assumptions of (i) Virtual short circuit between the two terminals of the op-amp (ii) The current drawn by the terminals is zero [7].

$$I = \frac{V - V_1}{Z_1} \tag{1}$$

$$\frac{V_1 - V}{Z_2} + \frac{V_2 - V}{Z_3} = 0 \tag{2}$$

$$\frac{V_2 - V}{Z_4} + \frac{0 - V}{Z_5} = 0 \tag{3}$$

Eliminating V_1 and V_2 and solving them for the ratio V/I gives the impedance of GIC as

$$Z = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4} \tag{4}$$

By suitably selecting the impedances as, $Z_1 = R_1, Z_2 = X_{C2}, Z_3 = R_3, Z_4 = R_4, Z_5 = R_5$ the impedance of the circuit is

$$Z = \frac{sR_1 R_3 R_5 C_2}{R_4} \tag{5}$$

This is equivalent to an inductor, where $L = \frac{R_1 R_3 R_5 C_2}{R_4}$. The value of L is obtained by properly selecting the values of the resistances and capacitances. If $R_1 = R_3 = R_5 = R_4 = R$ and $C_2 = C$ then

$$L = CR^2 \tag{6}$$

3. Single tuned amplifier

The basic block diagram of the single tuned amplifier is given in the Fig.2. The circuit consists of a common emitter amplifier [8] with the tank circuit. To design the tuned amplifier for a frequency of 100 Hz and assuming C= 0.1 μF, the requirement of L is 2.54H. Such a large value of inductor is impossible to realize. Hence the inductor value of L= 2.54 H is replaced by the simulated inductor given by the equation (6). The gain of the amplifier is chosen as 6.04 with the input of 1V. The design values of the common emitter amplifier and the simulated inductor are given in the Appendix A. The frequency response of the single tuned amplifier for the frequency of 100 Hz is shown in the Fig.3.

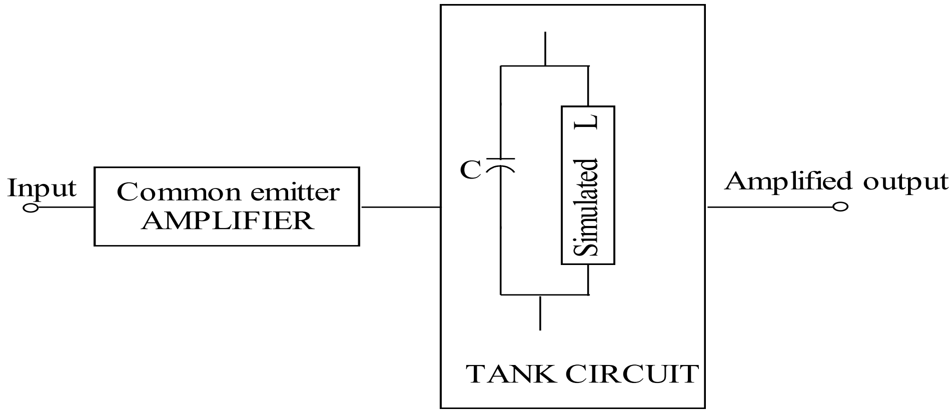

Fig.2. Block diagram of single tuned amplifier

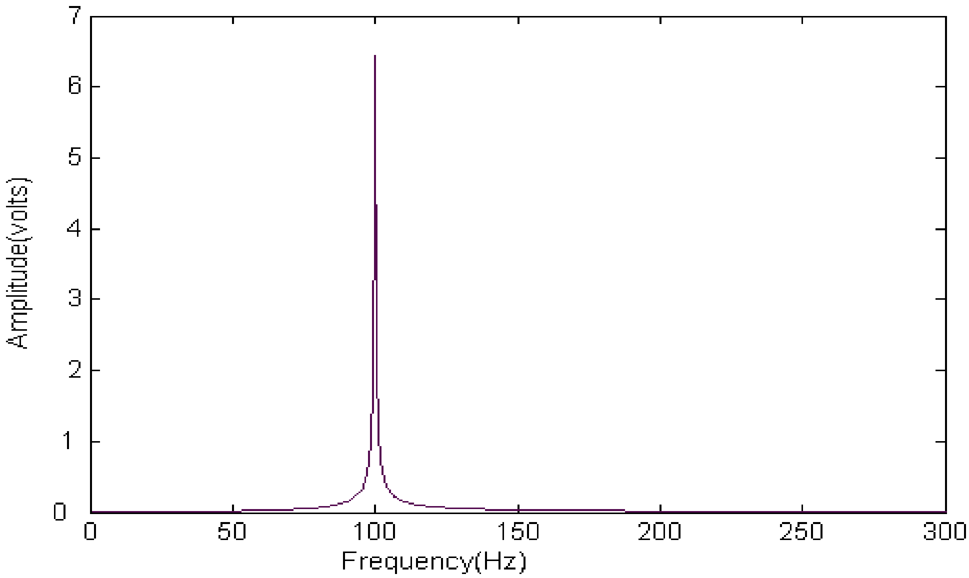

Fig.3. Frequency response of single tuned amplifier

4. Hartley oscillator and Colpitts oscillator

The essential features of LC oscillators are (i) the tank circuit determines the frequency of oscillation (ii) the amplifier amplifies the oscillations produced by the tank (iii) the network in the feedback path provides positive feed back. A Hartley oscillator is essentially any configuration that uses two series-connected coils and a single capacitor in the feedback network. There is no need to have mutual coupling between the two coil segments. It consists of two inductors in series, which need not be mutual and one tuning capacitor.

The frequency of oscillation for Hartley oscillator is given by

$$f_0 = \frac{1}{2\pi\sqrt{(L_1 + L_2)C}} \tag{7}$$

$$\text{If } L_1 = L_2 = \frac{L}{2} \quad \text{then } f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{8}$$

The frequency of oscillation for Colpitts oscillator is given by

$$f_0 = \frac{1}{2\pi\sqrt{\left(\frac{C_1 C_2}{C_1 + C_2}\right)L}} \tag{9}$$

$$\text{If } C_1 = C_2 = 2C \quad \text{then} \quad f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{10}$$

The basic block diagrams of the Hartley oscillator and the Colpitts oscillator are shown in Fig.4 and Fig.5 respectively. To design the oscillator for 100 Hz and assuming C=0.1µF, the value of L is 1.268H for Hartley, using equation (7) and 2.536 H for Colpitts using the equation (10). Since such a large value is physically not realizable, the passive component L is replaced by the simulated L. The design of oscillators which includes the amplifier and the tank circuit consisting of simulated inductor are given in the Appendix B. The mutual inductance is neglected in the design. The output of the oscillator given in the Fig.6 is similar, for both the LC oscillators designed for 100Hz.

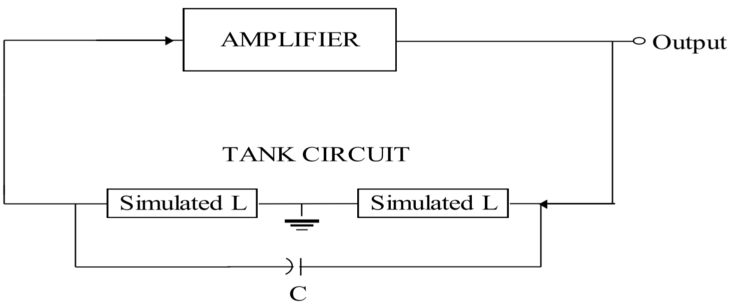

Fig. 4. Block diagram of Hartley oscillator

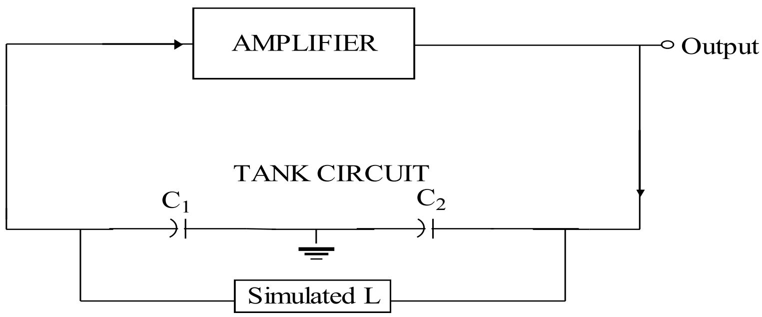

Fig.5. Block diagram of Colpitts oscillator

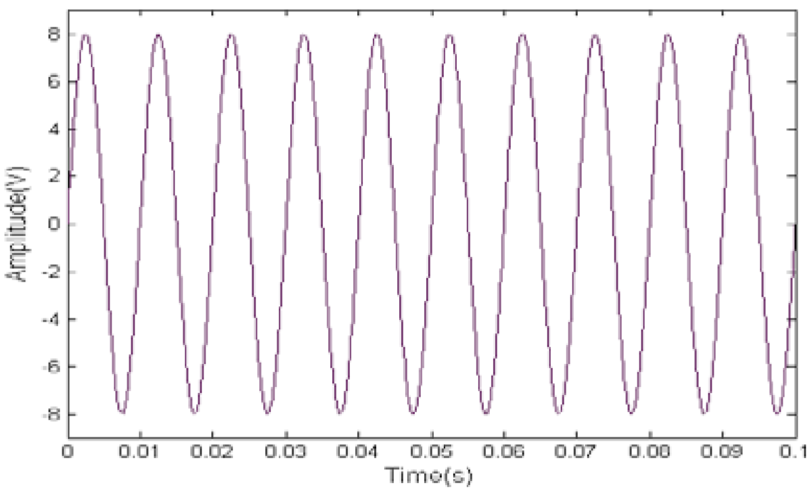

Fig.6. Output wave form of Hartley oscillator and Colpitts oscillator for 100Hz

5. Conclusion

The realization of single tuned amplifiers and LC oscillators at low frequencies are impossible using passive component. Hence simulated inductor is used to design such circuits. The simulation circuit for L is presented. The design of tuned amplifier, Hartley and Colpitts oscillators and the simulated responses obtained using PSPICE are presented. .

References

[1] Umesh Kumar and Sushil Kumar Shukla, “Analytical study of inductor simulation circuit” , active and passive Elec.comp, vol. 13, pp 211-227, 1989.

[2] W.Zhuo, de Gyvez, J.P, Sanchez-Sinencio, E, “Programmable low noise amplifier with active-inductor load ’’, Proceedings of the IEEE International Symposium on Circuits and Systems, Vol.4, pp 365 - 368, 1998 .

[3] Adel S.Sedra and Kenneth C.Smith, “Microelectronic circuits’’, Oxford University Press, Sixth edition, 2010

[4] D.Susan, S.Jayalalitha, "Analog filters using Simulated Inductor", Proceeding of IEEE, 2nd International Conference on Mechanical and Electrical Technology (ICMET), Singapore 2010, pp 659-662.
[5] D.Susan, S.Jayalalitha, "Synthesis of low pass filter using Frequency Dependent Negative Resistances", International Journal of Electronic and Electrical Engineering, vol. 3, pp 263-269. 2010.
[6] D.Susan, S.Jayalalitha, "Spectral purity of sine wave", An International Journal of Analog integrated circuits and signal Processing, (under review), 2011.
[7] Sergio Franco, "Design with operational amplifier and analog integrated circuits", McGraw Hill international second Edition, 1998.
[8] L.T Bruton "Multiple-Amplifier RC –Active filter design with emphasis on GIC realizations", IEEE Transaction on Circuits and systems, Vol Cas-25, No 10, October 1978.

Appendix A. (Single Tuned Amplifier)

$$Amplifier\ \ Design:$$
$$Given\ :\quad V_{CC}=10V, I_C=10mA, \beta=150, S=2$$
$$Designed\ \ values:$$
$$Voltage\ \ Dividers:\ \ R_1=5.9647K\Omega, R_2=1.222k\Omega$$
$$Stabilization\ resistor\ \ and\ \ Capacitor:\ R_E=1k\Omega, C_E=50nF$$
$$Tank\ \ circuit\ \ Design:$$
$$f_0=100hz, C=1\mu F\quad L=2.536H$$
$$Simulated\ \ L\ \ design:$$
$$L=CR^2\quad C=1\mu F\ \ R=1.592k\Omega$$

Appendix B. (oscillator)

$$Amplifier\ \ Design:$$
$$Given\ :\quad V_{CC}=10V, I_C=10mA, \beta=150, S=2$$
$$Designed\ \ values:$$
$$Voltage\ \ Dividers: R_1=33k\Omega, R_2=13.99k\Omega$$
$$Stabilization\ resistor\ \ and\ \ Capacitor: R_E=1k\Omega, C_E=1.67\mu F$$
$$Tank\ \ circuit\ \textbf{(Hartely oscillator)}\ Design:$$
$$f_0=100Hz, C=1\mu F\quad L_1=L_2=1.268H$$
$$Simulated\ \ L\ \ design:$$
$$L=CR^2\quad C=1\mu F\ \ R=1.126k\Omega$$
$$Tank\ \ circuit\ \textbf{(Colpitts oscillator)}\ Design:$$
$$f_0=100Hz, C_1=C_2=2\mu F\quad L=2.536H$$
$$Simulated\ \ L\ \ design:$$
$$L=CR^2\quad C=1\mu F\ \ R=1.592k\Omega$$